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(54) **Fuel rod support grid**

(57) A grid for the support of nuclear fuel rods (1) arranged in a triangular array is formed by concentric rings (4) of straps (3) joined by radially arranged web sections (22).

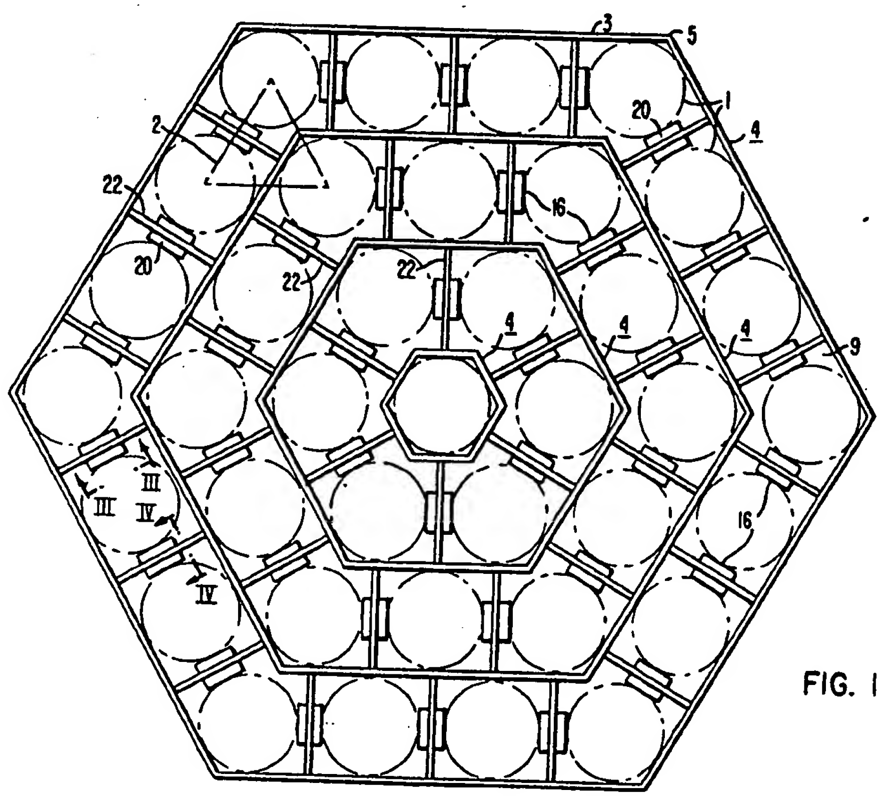

FIG. 1

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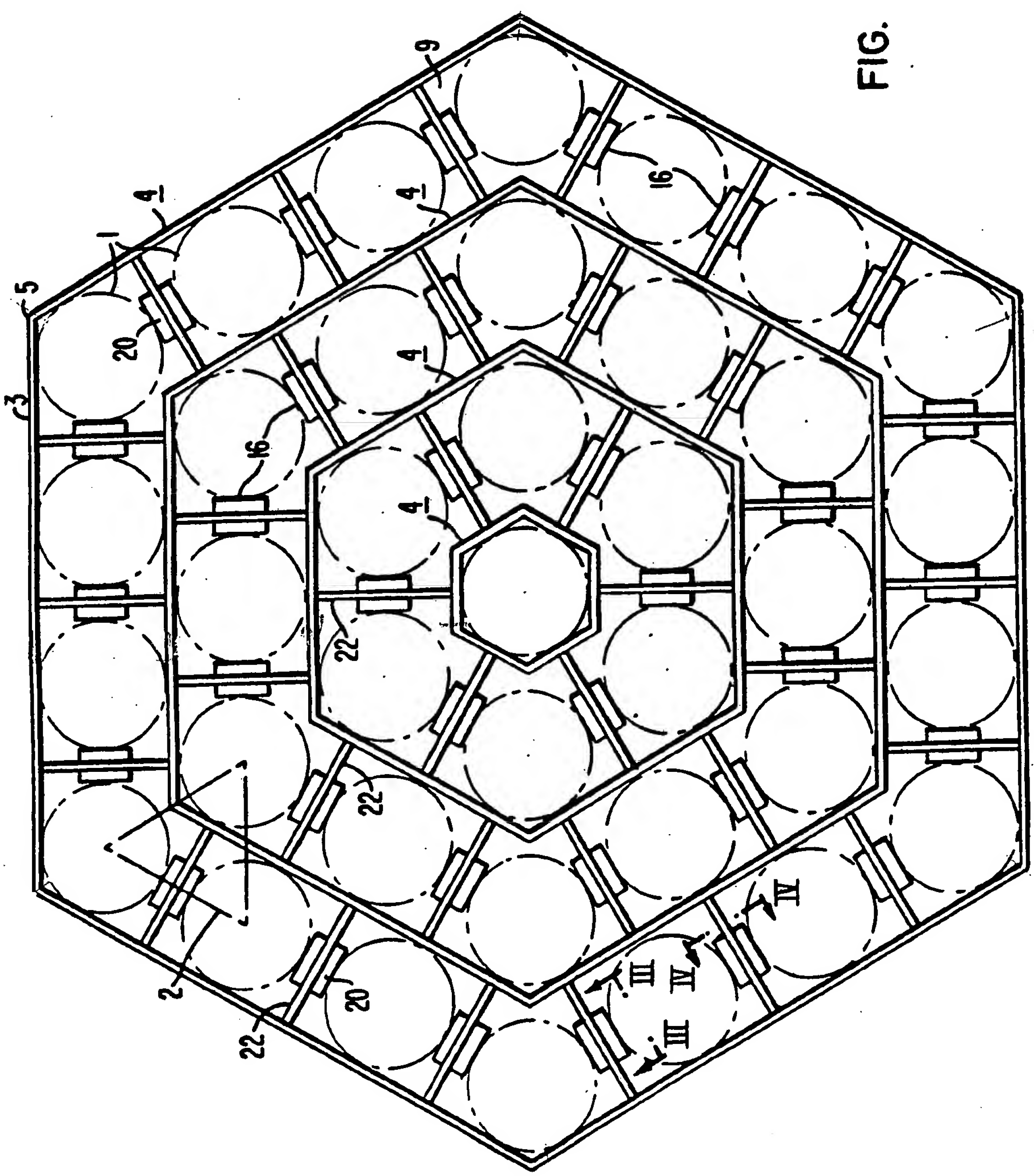
FIG. 1



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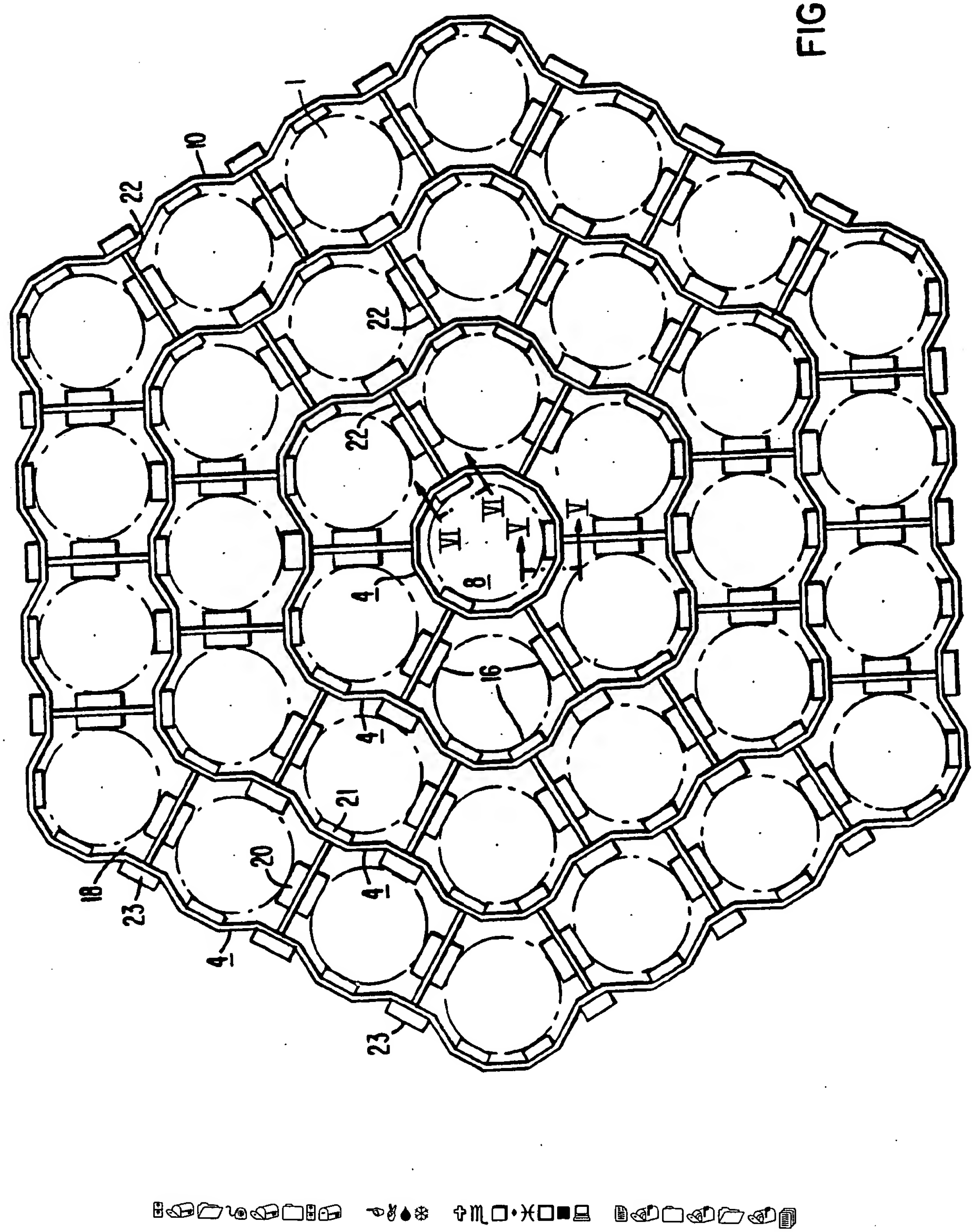

FIG. 2

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FIG. 3

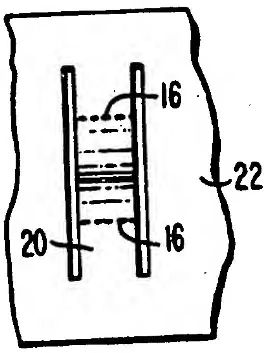


FIG. 4

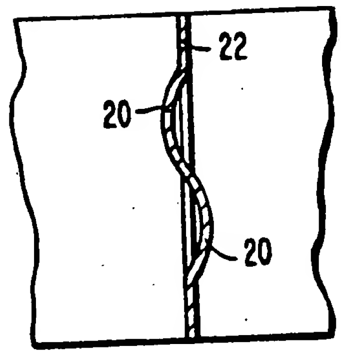


FIG. 5

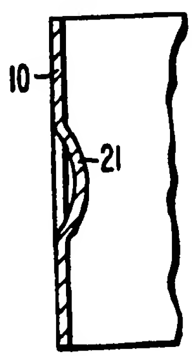


FIG. 6

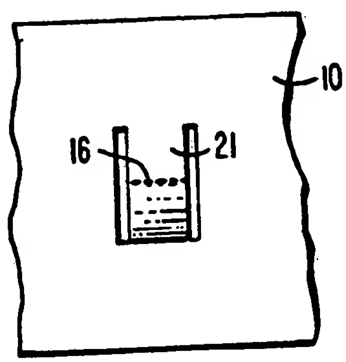
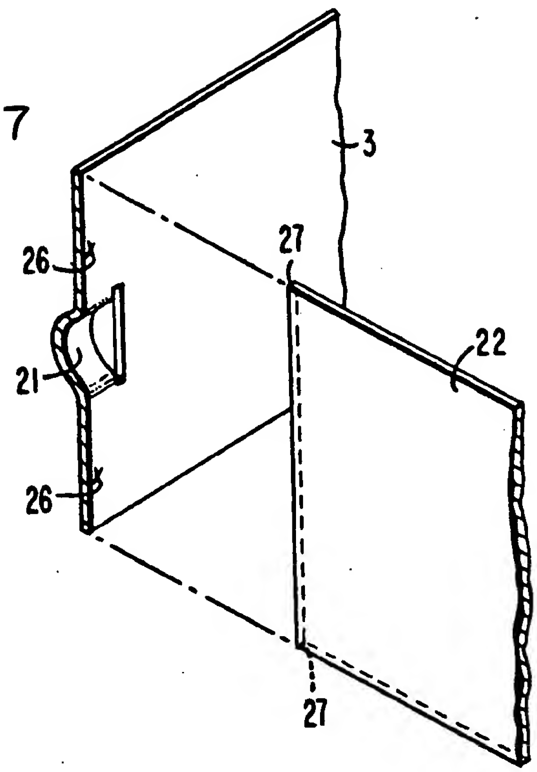


FIG. 7



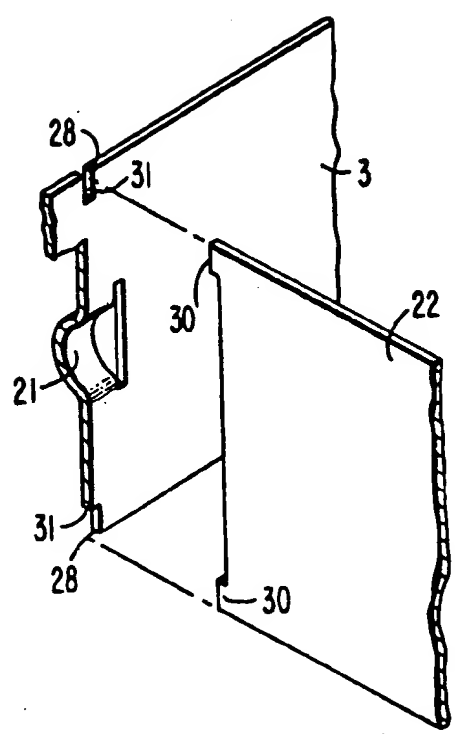


FIG. 8

SPECIFICATION

Fuel rod support grid

This invention relates to a new design for a support grid for triangular arrays of nuclear fuel rods, especially for hexagonal fuel assemblies for sodium-cooled fast reactors.

The core of a nuclear reactor usually consists of a grouping of fuel assemblies. Each fuel assembly is a grouping of cylindrical fuel rods which are arranged and supported by grids which are spaced axially along the fuel assembly. The support grids define the geometric pattern of cells for the fuel rods and maintain the correct spacing between rods.

Some nuclear reactor designs specify hexagonal fuel assemblies, with fuel rods arranged in a triangular array. A triangular array of rods is defined herein as a geometric pattern of rods in which three imaginary lines joining the centers of any three mutually adjacent rods in the assembly form an equilateral triangle. The triangular array is repetitious such that the family of all imaginary triangles formed by the centers of all possible groups of three mutually adjacent rods in the assembly consists of congruent triangles. The prior art provides grids for triangular arrays, but these, as shown below, have fabrication and technical disadvantages.

Hexagonal grids for a triangular array of rods consists of stacks of many deeply corrugated straps which stack is wrapped with a strap which then forms the enclosing member of the grid.

The stacking of corrugated straps results in the creation of double walls at periodic locations in the grid. These double walls constitute flow restrictions in the final fuel assembly.

The depth of the corrugations in a strap may vary during manufacturing due, for example, to stamping die wear. Experience has shown these variations in depth to be trending rather than statistical, such that all straps in a manufactured batch may have a depth slightly deeper (or shallower) than designed. In the stacking operation presently used to construct grids, the deviations are cumulative, such that the height of the fina grid becomes distorted. This distortion problem originates at the strap stamping stage, but is only manifested later in the stacking stage of fabrication at which time the only capability to adjust to dimensional variations is the flexibility of the dimples. The practical result is that the sum of the cumulative deviations occasionally exceeds the dimple flexibility such that some rods cannot be inserted and the entire grid must be discarded.

A variety of manufacturing problems introduces variation in the exact placement of the dimples. Such variation causes the rod to be more or less firmly secured than desired since even a slight shift in dimple position changes the distance between dimple contact points within a cell.

The fabrication of an annular grid (a grid with an empty center) is presently accomplished by the fabrication of a complete grid by stacking, cutting to a hexagonal outside shape and banding the outside surface, followed by the cutting out and removal of the center section, and banding of the inside hexagonal surface. The need to fabricate a complete grid is occasioned by the nature of the stacking method wherein the positioning, alignment, and support of a strap during welding is achieved by reference to the previously welded strap. The center section of the grid cannot be merely omitted since it has a fabrication process role. All the labor and material associated with this center region is presently wasted. Moreover, the resulting annular grid must have a least two rows of fuel rod holes such that a mechanically sound structure is maintained during the cutting operation.

It is therefore the principal object of the present invention to provide a grid supporting fuel rods in a triangular array, which grid can be manufactured without the stacking of straps and without the extra manufacturing operations to form annular or polygonal grids.

With this object in view, the present invention resides in a support grid for supporting nuclear fuel rods in a triangular array, consisting of interconnected metal straps, characterized in that said straps are arranged in the form of a plurality of rings disposed concentrically with a plurality of webs extending radially between adjacent rings and attached to adjacent rings thereby defining cells for receiving nuclear fuel rods such that the arrangement of cells is a triangular array.

This web and strap construction is applicable to fuel assemblies of polygonal cross-section, such as a hexagonal assembly. The preferred embodiments discussed below relate to hexagonal fuel assemblies.

The invention will become more readily apparent from the following description of preferred embodiments thereof shown in the accompanying drawings, in which:

Figure 1 is a straight-strap embodiment of the invention;

Figure 2 is a corrugated-strap embodiment of the invention;

Figures 3 and 4 are views from Figure 1 as indicated, showing details of a double dimple;

Figures 5 and 6 are views from Figure 2 as indicated, showing details of a single dimple; and

Figures 7 and 8 show details of strap-to-web joints.

The present grid is shown in one embodiment in Figure 1 which shows a grid which supports thirty-seven cylindrical fuel rods 1 in a triangular array 2, forming a hexagonal assembly. The flat straps 3 are formed into hexagonal rings 4 and welded at the corners 5. Radial webs 22 extend only between adjacent rings 4 and are welded to the flat straps 3 at each end of the web 22 forming cells 9 receiving the fuel rods 1. Double dimples 20 are integral with the web 22. The central cell 8 as shown in Figure 2 has dimples on the ring strap 4.

Figures 3 and 4 are views from Figure 1 which show the details of a double dimple 20. Figures 5 and 6 are views from Figure 2, which show the

details of a single dimple 21 used to support the center rod in Figure 1. These dimples 20, 21 are structures integral to the strap or web material.

The present grid is not fabricated by the stacking method, and does not have a cumulative deviation problem. The grid can be assembled in a welding fixture which receives and temporarily supports the flat straps in the appropriate shape and location. Any variation in cell size is due to the characteristics of the welding fixture which can be detected and corrected before grid fabrication. The grid cell is completed by selection and installation of webs 22 such that a tight fit is accomplished. If butt weld joints as shown in Fig. 7 are used, the tight fit is achieved by the use of webs of slightly varying length, selected as needed. If a tongue-and-groove weld joint as shown in Fig. 8 is used, the slip of the joint may be used to achieve the tight fit such that only standard webs of a single size are needed. The final deviation in cell size is not cumulative over the grid. Obviously, any deviation existing will, in this new design, be within the adjustable range of the dimples in all but most unusual circumstances.

The flat-leaf, single and double dimples 20, 21 in this invention have line-contact areas 16 (Figures 1, 2) such that small deviations of fuel rod positions will not result in looseness.

The final grid has no double wells such that less flow restriction is anticipated.

The grid represented in Figure 1 is useful for certain applications, but cannot accommodate a fuel rod array in which the rods are closer together such that no line-of-sight gap exists between rods adequate to admit the hexagonal rings 4 of flat strap 3.

Figure 2 is an embodiment of the invention in which corrugated straps 10 are used to fabricate the hexagonal rings 4. This grid has closely-spaced fuel rods and has no line-of-sight clearance between adjacent rod rings.

In this design, the dimples occur in both web positions and strap positions. Figures 3, 4, 5, and 6 show details of the double dimples 20 (Figure 4) and single dimples 21 (Figures 5, 6). The center rod 8 may be supported by additional dimples over the three shown in Figure 2.

The construction technique for this second embodiment also involves the use of tongue-and-groove joints or variable-length webs 22 each extending between adjacent rings 4 only. The same advantages as enumerated for the first embodiment apply. Deviations in the depth of the corrugations in the corrugated strap 10 will affect only cells adjacent to the particular strap, are not cumulative across the grid, and therefore within the adjustment range of the support dimples. The corrugated strap 10 may still be supported in a welding fixture since the use of tongue-in-groove joints or webs of varying length will provide the flexibility needed to adjust to the depth deviations.

Figure 2 shows single dimples 21 at location 23 which are unused. These are shown in the drawing since the use of standardized corrugated strap 10 for all hexagonal rings 4 results in the existence of these unneeded dimples. These may alternatively be omitted.

Both embodiments employ a web and strap construction which involves the joinder of web and strap members while these are supported and formed into the desired grid shape in a welding fixture comprising grooved plates and a welding machine. The strap sections are cut to the appropriate lengths to form the needed rings from previously prepared standard strap which has the dimples already constructed at appropriate intervals. The standard strap may be prepared in standard lengths or even in large rolls. The strap sections are inserted into the grooves in the welding fixture plates which shapes the strap into hexagonal rings of predetermined size. Web sections are inserted into welding fixture plate grooves which bring these webs into suitable proximity for welding to the rings. It is at this step when webs of slightly varying length are chosen to ensure affirmative contact with the rings and accommodate slight variations in ring-to-ring distance.

The welding may be by electron beam, resistance, laser or other methods.

Figure 7 shows a butt joint between the web and strap in which the strap 3 is resistance-welded at points 26 and welded by electron beam or other method at contact lines 27.

Figure 8 shows a tongue and groove joint between the web and strap, with welds at double contact lines 28. The tongue and groove method allows some flexibility of fit of a standard web length to accomodate small variations in ring-to-ring spacing due to the slide of the tongue 30 in the groove 31 while still providing welding double contact lines 28. This feature may reduce or eliminate the need for variable length web.

The grids in Figures 1 and 2 are shown for convenience to be for relatively small assemblies. In practice, the grid can be adapted to support many more rods in larger assemblies.

CLAIMS

1. A support grid for supporting nuclear fuel rods in a triangular array, consisting of interconnected metal straps, characterized in that said straps (4, 10) are arranged in the form of a plurality of rings disposed concentrically with a plurality of webs (22) extending radially between adjacent rings (4, 10) and attached to adjacent rings (4, 10) thereby defining cells for receiving nuclear fuel rods (1), such that the arrangement of cells (9, 18) is a triangular array.

2. A support grid as claimed in claim 1, characterized in that said concentric rings (4) are of corrugated straps (10) to provide for a closely spaced triangular array of fuel rods (1).

3. A support grid as claimed in claim 1 or 2,

characterized in that said webs (22) are of varying length.

4. A support grid as claimed in claim 1, 2 or 3 characterized by spring dimples providing for a line-contact area (16) for said fuel rods (1).

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